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U.S. APPLICATION NO.

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INTERNATIONAL APPLICATION NO.
PCT/AU99/00479

INTERNATIONAL FILING DATE
17 JUNE 1999

PRIORITY DATE CLAIMED
17 JUNE 1998

TITLE OF INVENTION
Z AXIS TRACKER

APPLICANT(S) FOR DO/EO/US
Paul Phillip Van Saarloos

Applicant herewith submits to the United States Designated /Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a FIRST submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(I).
4. ☒ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☐ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
 - a. ☐ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
8. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11. to 16. below concern other document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A substitute specification.
15. ☐ A change of power of attorney and/or address letter.
16. ☒ Other items or information:

International Publication No. WO 99/65431 (incl. 20 page spec, 7pages claims and 1sheet drawing)
International Search Report
International Preliminary Examination Report
PCT Request
PCT Demand

INTERNATIONAL APPLICATION NO. 097719726		INTERNATIONAL FILING DATE 17 JUNE 1999		PRIORITY DATE CLAIMED 17 JUNE 1998	
17. [X] The following fees are submitted:				CALCULATIONS <small>PTO USE ONLY</small>	
Basic National Fee (37 CFR 1.492(a)(1)-(5)): Neither international preliminary examination fee (37 CFR 1.482) Nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO (1.492(a)(3)) \$1,000.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO (1.492(a)(5)) \$860.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO (1.492(a)(2)) \$710.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4) (1.492(a)(1)) \$690.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) \$ 100.00					
ENTER APPROPRIATE BASIC FEE AMOUNT				= \$1,000.00	
Surcharge of \$130.00 for furnishing the oath or declaration later than [] 20 [] 30 months from the earliest claimed priority date (37 C.F.R. 1.492(e)).				\$	
Claims	Number Filed	Number Extra	Rate	\$	
Total Claims	45 -20=	25	X \$ 18.00	\$ 450.00	
Independent Claims	4 -3=	1	X \$ 80.00	\$ 80.00	
Multiple dependent claim(s) (if applicable)				+ \$270.00 \$	
TOTAL OF ABOVE CALCULATIONS				= \$1,530.00	
Reduction by ½ for filing by small entity, if applicable. Verified Small Entity Status is claimed. (Note 37 CFR 1.9, 1.27, 1.28).				\$ 765.00	
SUBTOTAL				= \$ 765.00	
Processing fee of \$130.00 for furnishing the English translation later than [] 20 [] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				+ \$	
TOTAL NATIONAL FEE				= \$ 765.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property				+ \$	
TOTAL FEES ENCLOSED				= \$ 765.00	
				Amt. refunded	\$
				charged	\$
a. [x] A check in the amount of \$ <u>765</u> to cover the above fees is enclosed. b. [] Please charge our Deposit Account No. <u>02-4377</u> in amount of \$ <u> </u> to cover the above fees. A copy of this sheet is enclosed. c. [x] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. <u>02-4377</u> . A copy of this sheet is enclosed.					
NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.					
SEND ALL CORRESPONDENCE TO:					
BAKER BOTTS L.L.P. 30 Rockefeller Plaza New York, New York 10112-4498				Signature RONALD B. HILDRETH December 15, 2000 Date 19,498 Registration No.	

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant : Paul Phillip Van Saarloos
Serial No. : To be Assigned
Filed : To be Assigned
For : Z AXIS TRACKER

PRELIMINARY AMENDMENT

Assistant Commissioner of Patents

Washington, D.C. 20231

Sir:

Preliminary to the examination of the above-identified application, please make the following amendment to the claims:

In the Claims:

Amend claim 4, line 1, delete "2 or 3."

Amend claims 5, 7 and 8, lines 1, delete "any preceding claim" and insert --claim 1--.

Amend claim 9 line 3, delete "any one of claims 1 to 8" and insert --claim 1--.

Amend claim 14, line 1, delete "or 13".

Amend claim 16, line 1, delete "any one of claims 12 to 15" and insert --claim 12--.

Amend claim 18, line 1, delete "any one of claims 12 to 17" and insert --claim 12--.

Amend claim 24, line 1, delete "claims 22 to 23" and insert --claim 22--.

Amend claim 25, line 1, delete "any one of claims 21 to 24" and insert --claim 21--.

Amend claim 26, line 1, delete "any one of claims 21 to 25" and insert --claim 21--.

Amend claim 28, line 1, delete "any one of claims 21 to 27" and insert --claim 21--.

Amend claim 29, line 1, delete "any one of claims 21 to 28" and insert --claim 21--.

Amend claim 30, lines 2 and 3, delete "any one of claims 21 to 29" and insert

--claims 21--.

Amend claim 32, line 1, delete "any one of claims 21 to 31" and insert --claim 21--.

Amend claim 33, line 1, delete "any one of claims 21 to 32" and insert --claim 21--.

Amend claim 36 line 1, delete "or 35".

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Amend claim 38, line 1, delete "claims 36 and 37" and insert --claim 36--.

Amend claim 39, line 1, delete "any one of claims 34 to 36" and insert --claim 34--.

Amend claim 40, line 1, delete "any one of claims 34 to 39" and insert --claim 34--.

Amend claim 41, line 1, delete "any one of claims 34 to 40" and insert --claim 34--.

Amend claim 42, lines 2 and 3, delete "any one of claims 34 to 44" and insert

--claim 34--.


Amend claim 44, line 1, delete "any one of claims 34 to 43" and inset --claim 34--.

Amend claim 45, line 1, delete "any one of claims 34 to 44" and insert --claim 34--.

R E M A R K S

This amendment eliminates multiple dependency in the claims. No new matter is introduced by this amendment.

Respectfully submitted,



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Z AXIS TRACKER**The Field of the Invention**

The present invention relates to a method and apparatus for tracking the position of an object surface. The invention is especially useful in the accurate placement of a laser's focal point during surgical laser procedures, of application - for example - in operations involving intrastromal ablation of the cornea, in the refractive correction of the eye, and in phacoemulsification procedures, where the lens of the eye is liquefied for easy removal. The invention will be described in terms of these applications, but is not restricted thereto. For example, it will be understood that the present invention may be applied to other medical laser procedures in which depth tracking is required.

Background Art

Intrastromal Photorefractive Keratectomy (intrastromal PRK or IPRK), also known as intrastromal ablation, involves focusing a short pulsed (< 50 ns), near infrared or visible laser to a point inside the cornea. Unlike the excimer laser, short-pulsed visible and near infra-red lasers are not absorbed highly enough by biological tissue to cause photodissociation or "ablation". Instead, the mechanism of tissue removal involves plasma-mediated photodisruption, with the development of cavitation bubbles and shock waves beneath the laser's target zone. If a sufficient energy density is reached inside the tissue, optical breakdown occurs and a small volume of tissue at the laser's focal point is vaporised.

A number of studies have been conducted into the feasibility of using intrastromal PRK for correcting refractive errors of the eye (see for example Habib et al, "Myopic Intrastromal Photorefractive Keratectomy with the Neodymium - Yttrium Lithium Fluoride Picosecond Laser in the Cat Cornea", Archives of Ophthalmology (1995) 113:499-505 or Hoi et al, "Picosecond Laser in situ Keratomileusis with a 1053-nm Nd:YLF Laser", Journal of Refractive Surgery

(1996) 12:721-728. Intrastromal PRK leaves the corneal epithelium and endothelium intact, preventing potential complications such as infection, and facilitating wound healing. Tissue effects appear confined to the cornea's stromal area, with small thermal damage zones and the appearance of normal collagenous stroma by six months post-surgery, with the use of the ultrashort Nd:YLF laser in cat cornea (Habib, Speaker, Kaiser & Juhasz (1995)). Intrastromal PRK may therefore have the ability to provide a more predictable refractive outcome, with the prospect of fewer complications than may occur with conventional techniques. US Patent 5,112,328 describes a method and apparatus for applications involving intrastromal corneal ablation.

It has been suggested that the intrastromal technique can be used to remove an appropriate volume of tissue, to effect refractive correction in a similar fashion to those achieved in Laser-in-situ-Keratomileusis (LASIK) procedures, without the necessity of creating a flap, or to cut the flap during LASIK operations. The current microkeratomes used in refractive surgery such as LASIK are mechanical devices that have significant potential to malfunction, sometimes causing serious damage to a patient's eye. Using intrastromal ablation to create the flap in LASIK may be much easier than trying to use intrastromal ablation to effect a refractive change. The intrastromal flap has the potential to make LASIK a safer and simpler procedure to perform, without having to rely on the use of mechanical devices.

Although there may be significant advantages in using intrastromal ablation for procedures such as refractive laser surgery, the practical difficulties of aiming each laser pulse onto the correct location within the cornea has meant that IPRK is not yet routinely performed. In living eyes, the need to deposit each laser pulse in the correct spot places stringent requirements on tracking the eye not only in the horizontal and vertical directions but also in a longitudinal direction away from or towards the laser source (known as and referred to below as the "Z" direction). Techniques with the appropriate resolution to accurately track eyes undergoing

surgery in the Z direction have not yet been fully developed.

US Patent 5,162,641 describes an eye tracking system, based on the principle of confocal microscopy, for measuring depth movement in eye tissue during laser surgery. This invention uses an illuminating light, a pinhole and a detector, located behind the optics of a laser system, to monitor the depth of a reflection along the optical axis. The system is arranged so that the maximum intensity of light reflected from the eye is directed onto the detector unit. The eye tracker focuses on an anterior reflective surface, such as the corneal tear layer, or a similar reference point with a known relationship to the target of the laser beam, and not necessarily on the target itself. When the tissue in the laser beam's focus moves, signals from the photodetector/pinhole arrangement decrease. These signal changes are then used to drive the optics of the laser system to compensate for the tissue movement, thereby moving the objective lens and repositioning the laser's focus. Focus monitoring may also be achieved by dithering the pinhole/photodetector unit to determine the direction in which signal increase occurs.

US Patent 5,336,215 (Intelligent Surgical Lasers) teaches an eye stabilising mechanism for use with a computer controlled ophthalmic laser system, specifically for use in intrastromal PRK or phacoemulsification procedures. This laser delivery system employs suction to immobilise the eye. A contact lens with limbal suction eliminates the need for a non-contact eye tracking device. A moveable objective lens controls the position of the laser's focal point through the various tissues of the eye in the X and Y or Z directions. Nevertheless, devices such as the one described above are not ideal for use in intrastromal ablation procedures: they have the potential to raise intra-ocular pressure, deform the shape of the eyeball and cause discomfort to the patient. The contact lens must also be made to conform to the individual patient's corneal topography. In addition, the reliance on suction to hold a device on the eye is one of the main reasons why current microkeratomes cause complications.

A general technique that can be used to measure surface topography is optical coherence tomography (OCT), also known as short coherence length interferometry. OCT usually involves splitting light from a low coherence light source (such as a superluminescent diode) and transmitting part of that light to the
5 object of interest (for example, a cornea) and the rest to a reference surface (for example, a flat mirror). The light is then combined again at a detector. Only when the distance to the reference surface matches the distance to the object of interest do the light beams from the two paths interfere with each other to form intensity variations at the detector. The reference surface is usually scanned backwards
10 and forwards so the intensity variations at the detector form a signal that is easily detected using electronic filters.

US Patent 5,465,147 describes a general OCT-based system and technique for acquiring a digital image of a region of an object using a CCD array as a detector to image the interference pattern. In this case, a reference scatterer
15 is employed rather than a flat mirror and this scatterer is moved towards and away from the beamsplitter in a predetermined pattern to generate a detectable variable interference signal. It is also suggested that the scatterer be vibrated or dithered back and forth about a single depth point at a predetermined frequency in order to provide a series of two dimensional images in the transverse direction at that
20 single depth point.

US Patent 5,644,642 teaches a gaze tracking device that employs OCT. This device uses measured height information of the features of the eye to improve the accuracy of tracking the eye in the X and Y directions. An optical fibre is used to transmit radiation which has a short temporal coherence length
25 and is substantially spatially coherent, onto a scanning reference mechanism, which causes a focal spot of radiation to scan the plane of the pupil transversely across the pupil/iris boundary. A raster pattern or a coarse scan pattern featuring a grid of points is employed and information is collected at each point on the grid. Radiation reflected from the eye interferes with that coming from the reference

path, which has a known path length that may be varied intermittently. Output from the OCT device is then generated when the path length of the reflected radiation is equal to the reference path length. An identifiable signal is produced when the scan crosses the pupil/iris border, enabling the determination of depth information. A computer examines the position at which a change in depth exceeds a predetermined amount. Spatial coordinates are then used in conjunction with geometric equations to determine the pupil border and pupil centre.

Other ophthalmologic applications of OCT are noted in US patent 5491524, including the imaging of intraocular structures for determining a variety of measurements of the cornea, iris, crystalline lens and anterior chamber. The patent proposes an OCT corneal mapping apparatus that utilises a rotating helical reference mirror to generate a periodic variation of the detected interference signal. The height of the helical surface is set so that the depth scan provided by the optical path length variation of the reference arm of the interferometer setup is of the order of the corneal thickness, thereby reducing the scan volume and the data acquisition time. In a particular embodiment, a signal peak is detected in order to determine the depth of a particular corneal structure and successive such peaks are utilised to track the reference path retroreflector with the curve and shape of the cornea.

OCT thus provides an inexpensive, non-contact and non-invasive method of determining depth points within the eye. However, OCT apparatus of the prior art typically scan a reference surface around the full range of possible signals from above and below the corneal surface to the interior of the eye, as well as scanning in X, Y directions, which is not highly effective as a tracking technique. Moreover, OCT has not been proposed as a mechanism for accurate tracking during eye surgical procedures, probably because it would be viewed as too slow for this application.

It is therefore an object of the present invention to provide an improved

tracking method and apparatus that can track the movement of an object in the axial or Z direction and is preferably useful for this purpose in eye surgical procedures.

Summary of the Invention

- 5 The invention generally provides a method for tracking the position of an object surface, including generating an interference signal between light beams of short temporal coherence length respectively comprising a primary beam reflected or scattered from the object surface and a reference beam. A reference surface in the path of the reference beam is scanned about a position at which the
- 10 interference signal is generated, which position is thereby indicative of the position of the object surface. In one aspect of the invention, the position of the reference surface is controlled to maintain a predetermined point in the range of the scanning at the indicative position. In another aspect, the interference signal is modulated with a characteristic predetermined repetitive variation.
- 15 The invention also provides apparatus for tracking the position of an object surface, including interferometer means for generating an interference signal between light beams of short temporal coherence length respectively comprising a primary beam reflected or scattered from the object and a reference beam. A reference surface is disposed in the path of the reference beam, and the
- 20 apparatus further includes means for scanning the reference surface about a position at which the interference signal is generated, which position is thereby indicative of the position of the object surface. In one aspect, there is means for controlling the position of the reference surface to maintain a predetermined point in the range of the scanning at the indicative position.
- 25 In the other aspect, there is means to modulate the interference signal with a characteristic predetermined repetitive variation.

The reference surface preferably comprises reflection or scattering means.

Advantageously, the modulation is effected by additionally dithering the position of the reference surface.

Preferably, the control of the position of the reference surface is effected by dithering the reference surface about a location at which a peak interference
5 signal is detected, and maintaining said predetermined point at the indicative position in response to the peak interference signal.

In an advantageous application the object is the cornea or iris of an eye.

The invention also provides a method of performing a surgical procedure at a sequence of points in tissue, wherein the correct location of the points is
10 maintained by tracking the position of a related object surface according to the above described method. The surgical procedure may be a surgical laser procedure in which a laser beam is focused successively at the points in the tissue. The surgical procedure may comprise one or more of intrastromal photorefractive keratectomy, Laser-in-situ-Keratotomy procedures or laser
15 optical breakdown in phacoemulsification.

Preferably said ophthalmic laser surgery includes IPRK, cutting the flap in LASIK procedures, or phacoemulsification procedures.

Preferably said ophthalmic laser surgery includes optical breakdown caused by a short laser pulse within the tissue of the eye.

20 **Brief Description of the Drawing**

The invention will be further described by way of example only, with reference to the accompanying drawing, which is a schematic representation of OCT Z-axis eye tracking apparatus according to a preferred embodiment of the present invention, arranged for controlling the targeting of a laser beam being
25 employed for performing a surgical procedure in the subject eye.

Description of Preferred Embodiments

In the illustrated OCT tracking apparatus, a beam of light 2, of short temporal coherence and produced by light source 4, is directed through beam-splitter 6. Light source 4 is suitably a superluminescent diode, producing a beam of visible or near infrared light. Beamsplitter 6 splits the beam into a reflected reference beam 8 and a transmitted primary beam 10. The primary beam 10 is directed onto an appropriate surface 12 of the eye to be treated, eg the front surface of the cornea, while the reference beam 8 is directed onto a reflective reference surface in the form of a flat mirror 14. Mirror 14 is scanned backwards and forwards in the direction of the reference beam 8 by means of scanning mechanism 15 which has a primary scanner 18 and a secondary dither scanner 16.

Light reflected from the mirror 14 interferes with reflected light from the corneal surface 12 and produces a characteristic interference signal detectable at and by photo-detector 20, as reference mirror 14 is oscillated by primary scanner 18.

The position of mirror 14 is scanned or oscillated to vary the path length of reference beam 8: when the total path lengths of the primary and reference beams are equal, the output signal from detector 20 (and transmitted to filter 22) reaches a maximum intensity. Thus, the intensity of the electronic signal sent to filter 22 is dependent on the position of the reflecting corneal surface 12 and therefore on the depth of the point of interest within the cornea at which a treatment laser beam 30 is to be focused for effecting intrastromal PRK. The detected signal may be analysed with respect to the position of mirror 14 to determine the signal peak that coincides with the position of the surface 12.

Mirror 14 is not necessarily an optical surface, or of optical quality, and is advantageously such that the reflected signals at beamsplitter 6 are of a similar order of magnitude. For example, a typical detected magnitude for the return

signal for a cornea might be around 4% of the incident signal, and this should preferably be matched in the interfering reflected reference signal.

For more efficient and accurate tracking, secondary dither scanner 15 is provided to dither mirror 14 about a position previously determined with scanner 18 that corresponds to the surface 12, and the detected peak interference signal is used to drive an offset to the position of the scanner 16 by scanner 18 to keep the reflecting surface of mirror 14 in the middle of the dithered range. The dither scanner 16 introduces a characteristic predetermined repetitive variation in the detected interference signal that can be filtered for efficient tracking. The presence of this modulation of the interference signal optimises the speed and accuracy of the tracking by allowing extraction of the surface position with less problems with noise. For example, phase sensitive detection might be advantageously employed.

The nature of scanners 14, 126 is not critical to the invention, and a suitable choice is readily made by those skilled in the art from a wide variety of options. One approach of interest for either or both scanners is a spinning cam, in which the reference surface is a cylindrical surface oscillated in the optical path by an eccentric rotating cam driven by an adjacent motor.

A controller 32 manages the tracking apparatus, interpreting the filtered detector signal, detecting the peak interference signal, and controlling both of the scanners 16, 18, and is linked to a surgical laser system 35 that generates treatment beam 30 so that the beam 30 may be targeted to successive points inside the cornea in response to the tracking of the corneal surface. The form and structure of controller 32 and of its circuits and firmware will be readily apparent to those skilled in the art of tracking and control instrumentation.

By means of suitable optics, beam 30 is typically delivered to the eye on a common optical axis with primary tracking beam 10: it will of course be understood that the configuration of optical components may be very different from that

illustrated, which is intended only as a simplified optical diagram for the purpose of explaining the concepts of the invention.

The illustrated configuration enables the precise tracking of surfaces within the eye, in real time and high resolution. The apparatus scans mirror 14 only about a position corresponding to the peak of the electronic signal from filter 22. The scanning range is equal to approximately ± 1 to ± 10 microns around the surface of the cornea. This configuration is therefore capable of giving a very sensitive depth measurement in the Z direction (towards the eye) with a fast response time. The preferred use of the second dithered scanner contributes to the fast response and therefore contributes to overcoming the traditional expectation, noted earlier, that OCT is too slow for the present application. During surgical procedures, a controller interprets the signals and send instructions to a surgical laser system to adjust the focal point of the laser according to movements of the patient's eye.

The OCT method and apparatus according to the present invention can provide information regarding the axial position of the cornea, enabling an ablative laser to be accurately focused on a spot within the cornea during operations such as intrastromal ablation or cutting the flap during LASIK. However, even with Z-axis tracking, eye movements in the X and Y directions can still affect the placement of the laser beam. A second preferred embodiment of the present invention (not illustrated), therefore includes gaze tracking apparatus capable of tracking transverse eye movements. Any suitable means of horizontal and vertical eye tracking may be employed to detect alterations in the coordinates of the centre of the pupil, which indicate that horizontal or vertical eye movements have occurred. Adjustments in the laser's focal point can therefore be made in any direction, according to movements of the patient's eye.

Optional infrared lights may be included to track eye gaze in the horizontal and vertical directions.

Claims

- 1 A method for tracking the position of an object surface, including generating
an interference signal between light beams of short temporal coherence
length respectively comprising a primary beam reflected or scattered from
5 the object surface and a reference beam, scanning a reference surface in
the path of said reference beam about a position at which said interference
signal is generated, which position is thereby indicative of the position of
the object surface, and controlling said position of said reference surface to
maintain a predetermined point in the range of said scanning at the
10 indicative position.
- 2 A method according to claim 1 wherein said light beams of short temporal
coherence length are derived by splitting a single initial beam.
- 3 A method according to claim 2 wherein said splitting is effected at a
beamsplitter at which the interference signal is formed by return of said light
15 beams.
- 4 A method according to claim 1, 2 or 3 wherein said reference surface
comprises reflection or scattering means.
- 5 A method according to any preceding claim further including modulating
said interference signal with a characteristic predetermined repetitive
20 variation.
- 6 A method according to claim 5 wherein said modulation is effected by
additionally dithering the position of the reference surface.
- 7 A method according to any preceding claim wherein said control of said
position of the reference surface is effected by dithering the reference
25 surface about a location at which a peak interference signal is detected,

and maintaining said predetermined point at the indicative position in response to said peak interference signal.

8 A method according to any preceding claim wherein said object is the cornea or iris of an eye.

5 9 A method of performing a surgical procedure at a sequence of points in tissue, wherein the correct location of said points is maintained by tracking the position of a related object surface according to any one of claims 1 to 8.

10 10 A method according to claim 9 wherein said surgical procedure is a surgical laser procedure in which a laser beam is focused successively at said points in the tissue.

11 11 A method according to claim 10 wherein said surgical procedure comprises one or more of intrastromal photorefractive keratectomy, Laser-in-situ-Keratotomy procedures or laser optical breakdown in phacoemulsification.

12 12 A method for tracking the position of an object surface, including generating an interference signal between light beams of short temporal coherence length respectively comprising a primary beam reflected or scattered from the object surface and a reference beam, scanning a reference surface in the path of said reference beam about a position at which said interference signal is generated, which position is thereby indicative of the position of the object surface, and modulating said interference signal with a characteristic predetermined repetitive variation.

13 13 A method according to claim 12 wherein said modulation is effected by additionally dithering the position of the reference surface.

- 14 A method according to claim 12 or 13 wherein said light beams of short temporal coherence length are derived by splitting a single initial beam.
- 15 A method according to claim 14 wherein said splitting is effected at a beamsplitter at which the interference signal is formed by return of said light beams.
- 5
- 16 A method according to any one of claims 12 to 15 wherein said reference surface comprises reflection or scattering means.
- 17 A method according to any one of claims 12 to 16 wherein said object is the cornea or iris of an eye.
- 10 18 A method of performing a surgical procedure at a sequence of points in tissue, wherein the correct location of said points is maintained by tracking the position of a related object surface according to any one of claims 12 to 17.
- 15 19 A method according to claim 18 wherein said surgical procedure is a surgical laser procedure in which a laser beam is focused successively at said points in the tissue.
- 20 A method according to claim 19 wherein said surgical procedure comprises one or more of intrastromal photorefractive keratectomy, Laser-in-situ-Keratomileusis procedures or laser optical breakdown in phacoemulsification.
- 20
- 21 Apparatus for tracking the position of an object surface, including:
- interferometer means for generating an interference signal between light beams of short temporal coherence length respectively comprising a primary beam reflected or scattered from the object and a reference beam;

a reference surface in the path of said reference beam;

means for scanning said reference surface about a position at which said interference signal is generated, which position is thereby indicative of the position of the object surface; and

- 5 means for controlling said position of said reference surface to maintain a predetermined point in the range of said scanning at the indicative position.
- 22 Apparatus according to claim 21 wherein said interferometer means includes a source of an initial beam and means for deriving said light beams of short temporal coherence length by splitting said initial beam.
- 10 23 Apparatus according to claim 22 wherein said source is a superluminescent diode.
- 24 Apparatus according to claims 22 and 23 wherein said interferometer means further includes a beamsplitter for effecting said splitting and at which the interference signal is formed by returned of said light beams.
- 15 25 Apparatus according to any one of claims 21 to 24 wherein said reference surface comprises reflection or scattering means.
- 26 Apparatus according to any one of claims 21 to 25 further including means to modulate said interference signal with a characteristic predetermined repetitive variation.
- 20 27 Apparatus according to claim 26 wherein said modulation means includes means to additionally dither the position of said reference surface.
- 28 Apparatus according to any one of claims 21 to 27 wherein said controlling means includes means to dither said reference surface about a location at

which a peak interference signal is detected, and to maintain said predetermined point at the indicative position response to said peak interference signal.

- 29 Apparatus according to any one of claims 21 to 28 configured for tracking
5 the position of the surface of the cornea or iris of an eye.
- 30 Surgical apparatus for performing a surgical procedure at a sequence of
points in tissue, including tracking apparatus according to any one of claims
21 to 29 for maintaining the correct location of said points by tracking the
position of a related object surface.
- 10 31 Apparatus according to claim 30 wherein said surgical procedure is a
surgical laser procedure and said apparatus includes a source of a laser
beam and means to focus the laser beam successively at said points in the
tissue.
- 32 Apparatus according to any one of claims 21 to 31 wherein said scanning
15 means comprises one or more of resonant, piezo or galvanometer scanning
means.
- 33 An apparatus according to any one of claims 21 to 32 wherein said
detecting means includes a silicon diode detector.
- 34 Apparatus for tracking the position of an object surface, including:
20 interferometer means for generating an interference signal between light
beams of short temporal coherence length respectively comprising a
primary beam reflected or scattered from the object and a reference beam;
a reference surface in the path of said reference beam;

means for scanning said reference surface about a position at which said interference signal is generated, which position is thereby indicative of the position of the object surface; and

5 means to modulate said interference signal with a characteristic predetermined repetitive variation.

35 Apparatus according to claim 34 wherein said modulation means includes means to additionally dither the position of said reference surface.

36 Apparatus according to claim 34 or 35 wherein said interferometer means includes a source of an initial beam and means for deriving said light
10 beams of short temporal coherence length by splitting said initial beam.

37 Apparatus according to claim 36 wherein said source is a superluminescent diode.

38 Apparatus according to claims 36 and 37 wherein said interferometer means further includes a beamsplitter for effecting said splitting and at
15 which the interference signal is formed by returned of said light beams.

39 Apparatus according to any one of claims 34 to 38 wherein said reference surface comprises reflection or scattering means.

40 Apparatus according to any one of claims 34 to 39 wherein said controlling means includes means to dither said reference surface about a location at
20 which a peak interference signal is detected, and to maintain said predetermined point at the indicative position response to said peak interference signal.

41 Apparatus according to any one of claims 34 to 40 configured for tracking the position of the surface of the cornea or iris of an eye.

- 42 Surgical apparatus for performing a surgical procedure at a sequence of points in tissue, including tracking apparatus according to any one of claims 34 to 41 for maintaining the correct location of said points by tracking the position of a related object surface.
- 5 43 Apparatus according to claim 42 wherein said surgical procedure is a surgical laser procedure and said apparatus includes a source of a laser beam and means to focus the laser beam successively at said points in the tissue.
- 44 Apparatus according to any one of claims 34 to 43 wherein said scanning means comprises one or more of resonant, piezo or galvanometer scanning means.
- 10
- 45 An apparatus according to any one of claims 34 to 44 wherein said detecting means includes a silicon diode detector.

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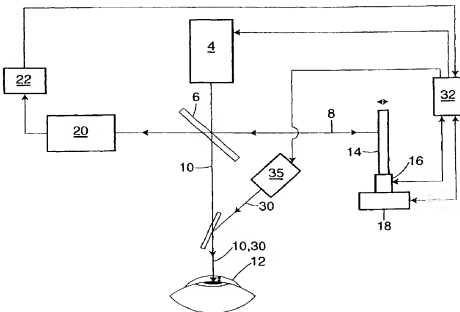
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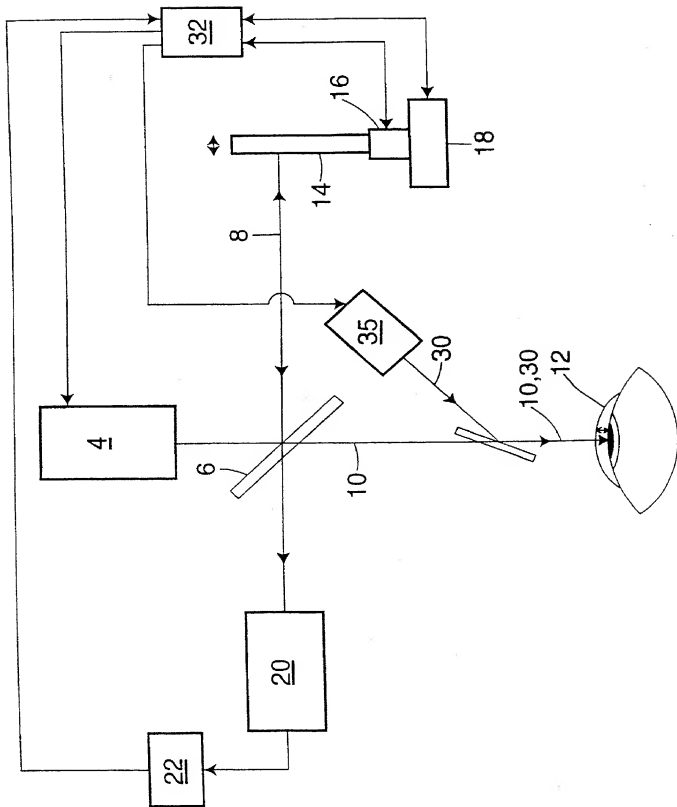
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(54) Title: Z AXIS TRACKER



(57) Abstract

A method of tracking the position of an object surface (12) includes generating an interference signal between light beams of short temporal coherence length respectively comprising a primary beam (10) reflected or scattered from the object surface (12) and a reference beam (8). A reference surface (14) in the path of said reference beam (8) is scanned at a position at which the interference signal is generated, which position is thereby indicative of the position of the object surface (12). In one aspect, the position of the reference surface (14) is controlled (16, 18) to maintain a predetermined point in the range of the scanning at the indicative position.





FILE NO.: A33827 PCT USA-062635.0132

COMBINED DECLARATION
AND POWER OF ATTORNEY

(Original, Design, National Stage of PCT, Divisional, Continuation or C-I-P Application)

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Z AXIS TRACKER

This declaration is of the following type:

- ☐ original
☐ design
☒ national stage of PCT.
☐ divisional
☐ continuation
☐ continuation-in-part (C-I-P)

the specification of which: (complete (a), (b), or (c))

- (a) ☐ is attached hereto.
 (b) ☒ was filed on December 15, 2000, as Application Serial No. 09/719,726 and was amended on December 15, 2000.
 (c) ☐ was described and claimed in PCT International Application No. filed on and was amended on (if applicable).

Acknowledgment of Review of Papers and Duty of Candor

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of the subject matter claimed in this application in accordance with Title 37, Code of Federal Regulations § 1.56.

- [] In compliance with this duty there is attached an information disclosure statement, 37 CFR 1.98.

Priority Claim

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) of any foreign application(s) for patent or inventor's certificate or of any PCT International Application(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT International Application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application on which priority is claimed

(complete (d) or (e))

- (d) ☐ no such applications have been filed.
 (e) ☒ such applications have been filed as follows:

09/19/26 .073001

FILE NO.: A33827 PCT USA-062635.0132

PRIOR FOREIGN PCT APPLICATION(S) FILED WITHIN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION			
COUNTRY	APPLICATION NO.	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Australian	PP4202	17/06/1998	<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
ALL FOREIGN APPLICATION(S), IF ANY, FILED MORE THAN 12 MONTHS (6 MONTHS FOR DESIGN) PRIOR TO SAID APPLICATION			
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			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>
			<input type="checkbox"/> YES <input type="checkbox"/> NO <input type="checkbox"/>

Claim for Benefit of Prior U.S. Provisional Application(s)

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below:

Provisional Application Number	Filing Date

Claim for Benefit of Earlier U.S./PCT Application(s) under 35 U.S.C. 120

(complete this part only if this is a divisional, continuation or C-I-P application)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior application(s) in the manner provided by the first paragraph of Title 35, United States Code § 112, I acknowledge the duty to disclose information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PCT/AU99/00479

17/06/1999

Pending

(Application Serial No.)

(Filing Date)

(Status) (pending, pending, abandoned)

(Application Serial No.)

(Filing Date)

(Status) (pending, pending, abandoned)

Power of Attorney

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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DATE	SIGNATURE OF INVENTOR		
FULL NAME OF FOURTH JOINT INVENTOR, IF ANY	LAST NAME	FIRST NAME	MIDDLE NAME
RESIDENCE & CITIZENSHIP	CITY	STATE or FOREIGN COUNTRY	COUNTRY OF CITIZENSHIP
POST OFFICE ADDRESS	POST OFFICE ADDRESS	CITY	STATE or COUNTRY
DATE	SIGNATURE OF INVENTOR		

Check proper box(es) for any added people forming a part of this declaration

- ☐ Signature for ninth and subsequent joint inventors. Number of pages added _____
- ☐ Signature by administrator(trix), executor(trix) or legal representative for deceased or incapacitated inventor. Number of pages added one
- ☒ Signature for inventor who refuses to sign, or cannot be reached, by person authorized under 37 CFR 1.47. Number of pages added 2